

This invention relates to a method for the separation and recovery of bitumen and oil from tar sands.

Tar sands or bituminous sand is an aggregate of sand, clay, oil and water. The sands consist mainly of quartz particles of about 100 to about 200 mesh size, although smaller sizes are sometimes present, as well as particles of other minerals and clay occurring interbedded with the bituminous sand. The oil can be described generally as being viscous, naphthenic and of a specific gravity slightly greater than that of water. The oil content of the sand varies substantially, but generally is up to about 17 percent by weight, or even higher. Rich bituminous sands from beds not invaded by water generally have a water content of about 3 to about 5 percent by weight. It is now generally believed that the water is probably present as a film around the sand particles with the oil surrounding the moist sand particles as an envelope.

Various methods have been proposed for the recovery and treating of the tar sands. One such method involves mining the tar sand and recovering the oil and bitumen therefrom by what is commonly known as the "hot water extraction process". The purpose of the hot water extraction process is to free the bulk or major portion of the oil contained in the tar sands to produce an effluent comprising bitumen with a minimum of water and entrained solids including sand. In the hot water extraction process, water at 185°F. and steam are added to the tar sands to raise the sand temperature and to facilitate the break-down of sand lumps into a fine dispersed state. The sand is then passed through a mixer to wet each sand particle further and to form a relatively stiff mixture referred to as a pulp. The pulp is then passed to a premix tank where it is flooded with additional water at 185°F. to effect separating of the bulk of the sand from the oil and to form an oil-air-sand-water mixture which is then distributed on to the surface of a separation tank wherein an oil-water-air froth separates and floats at the top of the separation tank. The froth contains a considerable amount of entrapped air in addition to entrained finely divided sand and clay particles or silt contained in the tar sands.



The froth is then treated in a zone to deaerate it, and the deaerated oil-sand-water mixture is diluted with a solvent for the oil, for example, a relatively light hydrocarbon fraction. This mixture is then passed to a dehydration zone, for example electrostatic heaters, where there is separation of the liquid-oil water mixture into an oil-rich phase and a water-rich phase so that the oil may be recovered for further treatment as desired.

The present invention is directed to an improved continuous hot water extraction process to obtain the froth rich in bitumen.

- One feature then of the present invention is the provision of an
- 10 apparatus for the continuous countercurrent separation and recovery of bitumen and oil from tar sands and in particular to an apparatus for the continuous countercurrent separation and recovery of bitumen and oil from tar sands wherein the bitumen is recovered at the upper portion of the apparatus and the sand and other waste material is recovered at the lower portion of the apparatus.

- Still another feature of the present invention is the provision of a continuous process for the countercurrent separation and recovery of bitumen and oil from tar sands in a vertically upright restricted zone, and in particular to a continuous process for the countercurrent separation and recovery of bitumen and oil from tar sands in a vertically upright restricted
- 20 zone, wherein the bitumen is floated-off from an upper region of said zone, the sand and other residue is discharged from a lower region of said zone and wherein a pulp of the tar sands is fed to an intermediate region of said zone.

- The present invention does not require the use of conventional regulators, depressants, activators, principal promoters, frothers, promoter-assisting agents and selectivity-assisting agents, which are well-known to those skilled in the art and which are selected for each of the desired ore. Nevertheless, they may be used. Conventional promoters or collectors, those reagents which provide ores to be floated with a water repellant surface that will adhere to air bubbles, include anionic agents, for example, the
- 30 xanthates, the dithiophosphates and the fatty acids and the cationic agents such as the fatty amine acetates. Non-limiting examples of such conventional promoters include:

- 1) Anionic agents, for example, xanthates for example, lauryl or octyl xanthates or a xanthate and Pb-Thallium group reaction product, thiophosphates, mercaptans, thioalcohols, thiocarbonallides, mercaptobenzothiazoles and organic sulphides, for example dixanthogens and thiuram disulphides;
- 2) carboxylic agents, for example fatty acids, for example aleric acid, tall oil, lalloel soap, naphthenic acid, black liquor soaps and cottonseed oil foots;
- 3) sulphony agents for example, turkey red oil, and higher alcohol sulphates, for example cetyl sulphate;
- 4) cationic agents, for example, amines, alkylalamines,  $\alpha$ -naphthylamines, onium salts, isoureas and aldoximes;
- and 5) fuel oil and kerosene.

Non-limiting examples of suitable regulators include sodium silicate, sodium hydroxide, sodium carbonate, polyphosphates, hydrogen fluoride, sulphuric acid, saturated brines and lime. Non-limiting examples of suitable depressants include excess sodium silicate, caustic starch, hydrogen fluoride, lactic acid, aluminium chloride, ferric chloride, sulphuric acid, starch, sodium hydroxide, quebracho, dichromate, Palcaton, Palconate, lime, bismuth nitrate, tannin, barium chloride, alum, bleaching powder, citric acid, gelatin, dextrine, and glue. Non-limiting examples of suitable activators include barium salts, lead salts, for example barium chloride and lead nitrate, phosphomolybdic acid, phosphotungstic acid, barium sulphide, copper sulphate, hydrogen fluoride, sodium sulphide, and ferric chloride.

Non-limiting examples of suitable frothers include cresylic acid, pine oil, aniline, xylidine, pyridine and eucalyptus oil. Non-limiting examples of suitable promoter-assisting agents include kerosene, fuel oil, aniline, pyridene, orthololuidine, various detergents, pine tar oil, higher alcohol sulphates and creosotes. Non-limiting examples of suitable selectivity assisting agents include sodium silicate, citric acid, hydrogen fluoride, starch, dextrine, quebracho, gum arabic, polyphosphates, sulphuric acid,

fluosilicates, dichromates, Falcaton, Falcotate, various acids, alum, alkali resins, sodium fluoride, caustic starch and guar gum.

The proportions of the various ingredients which may optionally be added to the tar sands is within the range well-known to those skilled in the froth-flotation art. Thus, the usual amount of promoters used is within the range of 0.01 - 0.2 lb/ton for the aryl dithiophosphoric acid type; 0.05 - 0.2 lb/ton for the xanthate type; 0.05 - 0.15 lb/ton for the thiocarbonyl type; 0.2 - 2.0 lb/ton for the fatty acid-type of vegetable origin; 0.1 - 0.5 lb/ton for the amine or amine salt type; 0.5 - 3.0 lb/ton for the anionic sulphionate-type; 0.2 - 2.0 lb/ton for the fatty acid or fatty acid soaps type; and 0.5 - 4.0 lb/ton for the kerosene or hydrocarbon type.

With respect to the various flotation modifying agents, the following proportions may be used:

- 1) Alkalies: lime, 0.5 - 5.0 lb/ton; soda ash or alkaline silicates, 0.5 - 3.0 lb/ton; sodium hydroxide, 0.5 - 4.0 lb/ton; and alkaline phosphates, 0.5 - 2.0 lb/ton;
- 2) Acids: sulphuric, 0.5 - 5.0 lb/ton; hydrofluoric and phosphoric, 0.5 - 4.0 lb/ton; and citric and tartaric, 0.5 - 2.0 lb/ton;
- 3) Cyanogen compounds: alkaline cyanides, 0.01 - 0.5 lb/ton; and ferrocyanides and ferricyanides, 0.1 - 2.0 lb/ton;
- 4) Sulphites and sulphides: alkaline sulphites, 0.5 - 4.0 lb/ton; sulphur dioxide, 1.0 - 10.0 lb/ton; hydrogen sulphide, 0.2 - 2.0 lb/ton; alkaline sulphides, 0.5 - 5.0 lb/ton; and alkaline oxychlorides, 0.5 - 2.0 lb/ton;
- 5) Salts of metal ions: copper sulphate, chromic acid and dichromates, 0.2 - 5.0 lb/ton; mercuric nitrate, lead nitrate, lead acetate, aluminum sulphate, aluminum chloride, manganates and permanganates; 0.1 - 2.0 lb/ton; and ferrous sulphate and ferric sulphate 0.1 - 1.0 lb./ton;

and 6) Organic colloids; quebracho, tannic acid, Palcoton and Palconate, and glue, 0.1 - 0.5 lb/ton; synthetic organic depressants, 0.1 - 1.0 lb/ton; and starch, 0.1 - 1.0 lb/ton.

In the case of frothers, in conventional practice they are used to enhance and assist in the introduction of small air bubbles into the flotation pulp and the collection of the unbroken mineral-laden bubbles on the pulp surface. For this purpose frothers such as the synthetic higher alcohol type have heretofore been used in amounts of from 0.01 - 0.5 lb/ton; pine oil has 10 been used in an amount of 0.03 - 0.2 lb/ton; while cresylic acid and encalyp-tus oil have been used in an amount of 0.05 - 0.2 lb/ton. However, in the present invention, the frother, if it is used at all, is used to control the air bubble size. To achieve this end, the amount of frother which may be used is generally less than that used heretofore. The bubble size is controlled in this manner preferably to achieve optimum surface area of the bubbles per volume of the column.

The rate of introduction of aqueous washing medium at the top of the vertically erect column, the rate of introduction of air at the bottom of the vertically erect column and the rate of introduction of feed slurry or pulp 20 at a point between the top and the bottom of the vertically erect column are all interdependent.

Stated in its broadest terms, however, the column should be operated at its optimum capacity for the percent solids in the tar sands pulp while retaining a maximum recovery, but at conditions which do not approach "flooding" conditions. By "flooding" conditions is meant that the downward velocity of the material in the column is such that it decreases the velocity of the rising bubbles to such an extent that more bubbles are produced than can escape from the top of the column. This results in a "compacted bubble condition" which leads to a violent swirling action and explosive ebullition 30 within the column, which severely hinders and may sometimes completely interfere with the separation.

Stated another way, moreover, the air pressure, which controls the rate of introduction of air at the bottom of the column, must be greater than the hydrostatic pressure on the means which provides the air bubbles i.e. the bubbles or diffuser. This expression may be expressed mathematically, as follows:

$$p = hd - k$$

where  $p$  is the pressure of air delivered to the bubbler or diffuser,

$h$  is the height of the column,

$d$  is the average density of the contents of the column

10 and  $k$  is a factor (which is greater than 0 but less than 7) which is a characteristic of the bubbler or diffuser.

A pressure of air of up to about 20 p. s. i. g. is usually used.

It is clear from the above formula and description that the amount of air passing through the column per unit time per unit area of cross-section of the column is a function of the slurry flow rate and the density of the slurry, the number of air bubbles, and the size of the air bubbles. The means to form the bubble of air may be any suitable perforated member. One type which has been found suitable is a conically shaped porous metal air diffuser, generally having perforations of a size 5 microns to 2500 microns  
20 with a size of 10 microns being particularly preferred. With perforations within this range, the bubble size would normally range from about 1000 to about 10,000 microns with a preferred size being about 1600 microns. Of course, as specified above, if a frother is used to control the bubble size, the bubble size can be maintained at a reasonable size even with larger perforations in the perforated member. A size of between 3000 microns and 6000 microns is permissible although other sizes are possible. Another type which has been found suitable is a cylinder having an elipsoidal cross-section, whose closed elipsoidal end is of porous metal having perforations of the sizes referred to hereinabove. Additionally porous metal plates having  
30 apertures of the sizes referred to hereinabove, porous ceramic plates having apertures of the sizes referred to hereinabove and other means such as punctured rubber, filter cloth, etc., with apertures of the sizes referred to

hereinabove are suitable. Such means must be connected to a source of air under pressure which is separated from the interior of the column except through such porous means.

In the present invention, the tar sands are formed into a pulp in an agitation conditioning tank, which contains means for intimately mixing the ground ore with the water, means for maintaining the temperature of water at about 170-190°F., and as well as necessary conditioning and flotation agents if desired. The pulp usually contains from about 10 to about 75% solids. The pulp from the agitation conditioning tank must be in pumpable form and is fed  
10 at such a rate that the pulp entering the column as feed contains more solids than are in the column at any particular instant of time. This may require changes in the flow rate and/or solids content of the pulp from time to time. The conditioning and flotation agents, if desired, are added in conventional quantities to the pulp in the agitation conditioning tank, and the required amount of frother to control the bubble size, if desired, is also added at this time.

The washing liquid entering at the upper portion of the column is water at a temperature between about 100°F. and the boiling point of water under the pressure conditions prevailing. A preferred temperature range is about 170-190°F. at atmospheric pressure. The rate of flow of such aqueous  
20 system is, as specified hereinabove, dependent upon the various parameters of the system. Generally speaking the rate of flow is such that it dilutes the slurry to prevent the unseparated slurry from rising.

By one broad aspect of this invention, there is provided a process for the separation of bitumen from tar sands, the process comprising, firstly, establishing and maintaining a downwardly flowing stream of water at a temperature between about 100°F. and the boiling point of water under the pressure conditions prevailing (a preferred temperature range being 170-190°F. at atmospheric pressure) within a vertically aligned, elongated zone; then establishing and maintaining an upwardly moving stream of air bubbles originating  
30 at a lower portion of that zone; then establishing a pulp of the tar sands with water at a temperature between about 100°F. and the boiling point of water under the pressure conditions prevailing (a preferred temperature range being 170-190°F. at atmospheric pressure); then introducing that pulp into that zone at

a region in the zone above the lower portion, at such a rate that the solids content of the slurry is greater than the solids content in said zone; then collecting the bitumen as overflow at the upper region of said zone; and finally discharging the other constituents of the pulp as underflow at the lower region of said zone.

Advantageously, the process is conducted by correlating the rate of input of water with the rate of input of pulp feed and the rate of underflow to maintain a substantially constant upper level in the column. Also the air bubbles may be produced by passing the air under pressure through a perforated member, the pressure being up to about 20 p. s. i. g. or even higher, the size of perforations being about 5 to about 2500 microns, with the air bubbles having a size of about 1000 to about 10,000 microns. The pulp usually has a solids content of about 10-50%.

By yet another aspect of this invention, there is provided an apparatus comprising: a vertically elongated column; means for introducing water at a temperature higher than ambient at the upper portion of the column; means associated with said column for maintaining said water at a temperature higher than ambient; means for introducing a feed pulp at an elevated temperature to an intermediate portion of the column; means for introducing air bubbles into the lower portion of the column; means for collecting bitumen and oil from said pulp from the upper portion of said column, and means for discharging another constituent of the pulp from the lower portion of the column.

The apparatus preferably includes an upper zone, an intermediate zone and a lower zone, at least the upper and intermediate zones, and preferably all three zones being hot water jacketed. The hot water inlet means usually extends into the upper portion of the upper zone. The hot pulp feed inlet is to the intermediate zone. The bubbler is situated in the lower zone and at the lower portion of the lower zone there is provided outlet means for the underflow. Collecting means are provided at the upper portion of the upper zone. Preferably, means are included for the preparation of the hot pulp feed.

A preferred feature of the invention is the reduction of the cross-sectional area of the upper zone by about  $1/4$  to  $3/4$  of the area of the other two zones, as by a reduction in its diameter or by insertion of an axial solid tube therein or an axial hot pulp feed line. In the latter case, the hot water inlet

means may be concentric with the hot pulp feed line. The bubbler may be a conical member with fluted perforated walls, or an elliptical cylinder, the top of which is perforated, these vessels being connected to a source of air under pressure. In each case the perforations may be about 5 to about 2500 microns in size. In another embodiment the upper collecting means includes a top chamber to an inclined weir therein and an inclined outlet cooperating with the weir.

In the drawings,

Fig. 1 is a schematic view partly broken away, of one embodiment of apparatus according to this invention,

10 Fig. 2 is a vertical cross-section of the flotation column of Fig. 1,

Fig. 3 is a section along the line III-III of Fig. 2,

Fig. 4 is a section along the line IV-IV of Fig. 2,

Fig. 5 is a vertical cross-section of a top portion of a flotation column according to another aspect of this invention,

Fig. 6 is a vertical cross-section of a top portion of a flotation column according to another aspect of this invention,

Fig. 7 is a vertical cross-section of a top portion of a flotation column according to yet another aspect of this invention,

20 Fig. 8 is a vertical cross-section of a top portion of a flotation column according to still another aspect of this invention,

Fig. 9 is a vertical cross-section of a bottom portion of a flotation column according to a further aspect of this invention, and

Fig. 10 is a section along the line X-X of Fig. 9.

Turning first to Fig. 1, the flotation column indicated generally at 10 comprises an upper section 11, an intermediate section 12 and a lower section 13. The cross-section of the flotation column may be circular, elliptical, square, rectangular or any other transverse section of a plain geometrical figure. As shown in Figs. 1 - 4, the cross-section of the column  
30 is circular. In addition the length of the column should be greater than the width thereof, and a ratio of length:width 6:1 or more has been found to be satisfactory. It is desirable to have the inside surfaces of the column smooth

to minimize turbulence.

As shown in Figs. 1 - 4, the column 10 is constructed of a plurality of sections in vertical axial alignment. Upper section 11 comprises two sections 14 and 15 which are each flanged to facilitate assembly by bolts or other means not shown in the drawings. As shown, both sections 14 and 15 of upper section 11 are jacketed by a water jacket 111, having hot water inlet means 114 and water outlet means 115.

Intermediate section 12 is compressed of a main flanged section 16 to facilitate assembly by bolts or other means not shown in the 10 drawings, and an integral inlet leg 17, also provided at its open end with a flange. As shown intermediate section 12 is jacketed by a water jacket 112, having hot water inlet means 116 and water outlet means 117.

The lower section 13 comprises a flanged main portion 18, a flanged inverted frusto-conical portion 19 and a flanged outlet portion 20 including a cylindrical section terminating in an inverted frusto-conical outlet 21. The frusto-conical outlet is attached to an elbow conduit 22 which conducts effluent from the column through valve 23 to outlet conduit 24. As shown, lower section 13 is jacketed by a water jacket 113, having hot water inlet means 118 and water outlet means 119.

20 Air under pressure in tank 25 is led by line 26 through valve 27 to a diffuser or bubbler 28 disposed in portion 19, by means of elbow pipe 29. As shown in Figs. 1 - 4, the diffuser or bubbler 28 is of approximately conical shape having its conical wall fluted vertically and provided with a plurality of small orifices. Air under pressure passes through such plurality of orifices and is delivered to the lower portion 13 of the column.

The hot pulp feed is pumped into the central portion 12 through inlet leg 17 which is preferably insulated by means of pump 30 from agitating conditioning tank 31. As shown, the tank 31 is jacketed by a water jacket 131, having hot water inlet means 120 and water outlet means 121. This 30 tank has a generally cylindrical shape, terminating in a frusto-conical bottom 32. Within the tank is an impeller 33 fixed to a vertical shaft 34 which is adapted to be rotated by means (not shown) associated with a pulley 35

splined to the shaft 34. The tank is provided with a removable cover 36, to enable tar sands to be added to the tank. Hot water, which forms the aqueous phase of the slurry, is admitted through insulated inlet conduit 37.

Downwardly flowing hot water is admitted to the upper portion 11 of the column 10 by means of valved insulated inlet conduit 38 which terminates in a feed tube 39 extending into the upper portion 11 of the column 10.

Foam, comprising bitumen, sand and water adhered to the rising air bubbles originating from diffuser or bubbler 28, collects in section 14 and is drawn-off through a downwardly disposed angularly extending discharge conduit 40, at the top of section 14.

Figs. 5-8 depict alternative constructions of the upper portion 11 of the column 10. In the embodiments shown in Figs. 5, 6 and 7 a means is provided in the upper zone to reduce the cross-sectional area thereof. This is for the main purpose of increasing the velocity of flow of the aqueous washing medium to enhance the contamination minimizing effect in the upper portion 11. In Fig. 5, this cross-sectional area reducing means comprises a solid tube 41 inserted in the region between the discharge conduit 40 and the inlet leg 17. In Fig. 6, the cross-sectional area reducing means is provided by forming the upper portion 11 between the discharge conduit 40 and the inlet leg 17 of a tube 15' of reduced diameter than the diameter of tube 18. In Fig. 7, the cross-sectional area reducing means is provided by a feed inlet conduit 43 extending downwardly along the longitudinal axis of the column 10 to a region corresponding to the intermediate portion 12. The conduit 43 is provided with a nozzle aperture 44. In addition, the aqueous washing medium is admitted through conduit 42 which is concentric with inlet tube 43.

The embodiment shown in Fig. 8 relates to a modified foam removal system. In that figure there is shown an enclosed box 45 having a plurality of sloping weirs 46 therein, leading to the discharge conduit 40. The foam is adapted to pass through the weirs 46 into zone 48 from which it is withdrawn through discharge conduit 40. The aqueous washing medium enters

through radial inlet tube 39 and its flow is directed by rims 47 upstanding from the upper tubular section 15.

The embodiment of Figs. 9 and 10 is directed to a modified diffuser or bubbler. The bubbler or diffuser 49 is an ellipsoidal cylinder having its bottom 50 of non-porous material and provided an inlet conduit 51 for the air under pressure admitted through line 29. Its sides are also non-porous, but its elliptical cross-sectioned top 52 is provided with a plurality of 10 micron diameter orifices.

The operation will now be described with reference to Fig. 1  
10 for the tar sands in which it is desired for the bitumen to be recovered as overflow.

Hot water at about 170-190°F., is passed downwardly through the column 10 from inlet conduit 38 and 39 and out through discharge line 22 and 24 through open valve 23. Air is admitted, under the required pressure to overcome the hydrostatic pressure, through lines 26 and 29 to the diffuser 28, where an upwardly directed stream of bubbles is caused to be directed through the column 10. The hot pulp of the tar sands of the desired solids content, is then pumped via pump 30 from tank 31 to inlet leg 17 and thence to the intermediate portion 12 of the column 10. The bitumen adheres to  
20 the air bubbles and is carried upwardly to be removed at discharge conduit 40. The sand and other extraneous material, is carried downwardly with the water and is discharged, along with the water, through discharge line 22 and 24.

The following Examples are given still further to illustrate the present invention.

Two samples of Athabasca tar sands were conditioned with hot water at a temperature of about 180°F. to form a pulp. One sample of pulp, Test I, had a solids content of 55% by weight and was pumped to the column. The other sample of pulp, Test II contained 50% solids and was  
30 pumped to the column. The results are tabulated below.

	<u>Test I</u>	<u>Test II</u>
Overflow:		
bitumen:	62.8%	67.4%
water:	30.3%	23.2%
mineral matter:	6.9%	9.4%
Underflow:		
Flow rate	800 ml/min.	700 ml/min.
% solids	12%	34%
oil:	0.20%	0.20%
10     water:	21.3%	6.4%
mineral matter:	78.5%	93.4%
Air:	1.5 s.c.f./hr	1.0 s.c.f./hr

These results show that bitumen can be very successfully separated from Athabasca tar sands in a continuous manner. The waste discharge contained only 2 parts per thousand of oil.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for the separation of bitumen and oil from tar sands, said process comprising:

- (a) establishing and maintaining a downwardly flowing stream of water at a temperature of from 100°F. to the boiling point of water under the pressure conditions prevailing within a vertically aligned, elongated zone;
  - (b) establishing and maintaining an upwardly moving stream of air bubbles originating at a lower portion of said zone;
  - (c) establishing a hot pulp of said tar sands at a temperature of from 100°F. to the boiling point of water under the pressure conditions prevailing;
  - (d) introducing said hot pulp into said zone at a region in said zone above said lower portion at such a rate that the solids content of said slurry is greater than the solids content in said zone;
  - (e) collecting said oil and bitumen as a foam as overflow at the upper region of said zone;
- and (f) discharging another constituent of said tar sands, as underflow at the lower region of said zone.

2. A process for the separation of bitumen and oil from tar sands, said process comprising:

- (a) establishing and maintaining a downwardly flowing stream of water at a temperature of about 170-190°F. at atmospheric pressure within a vertically aligned, elongated zone;
- (b) establishing and maintaining an upwardly moving stream of air bubbles originating at a lower portion of said zone;
- (c) establishing a hot pulp of said tar sands at a temperature of about 170-190°F. at atmospheric pressure;
- (d) introducing said hot pulp into said zone at a region in said zone above said lower portion at such a rate that the solids

content of said slurry is greater than the solids content in said zone;

- (e) collecting said oil and bitumen as a foam as overflow at the upper region of said zone;
- and (f) discharging another constituent of said tar sands, as underflow at the lower region of said zone.

3. A process for the separation of bitumen and oil from tar sands, said process comprising:

- (a) establishing and maintaining a downwardly flowing stream of water at a temperature of about 170°F. within a vertically aligned elongated zone;
- (b) establishing and maintaining an upwardly moving stream of air bubbles originating at a lower portion of said zone;
- (c) establishing a hot aqueous pulp of said tar sands at a temperature of about 180°F.;
- (d) introducing said hot pulp into said zone at a region in said zone above said lower portion at such a rate that the solids content of said slurry is greater than the solids content in said zone;
- (e) collecting said gangue bitumen and oil in the form of a foam as overflow at the upper region of said zone;
- and (f) discharging other constituents of said tar sands as underflow at the lower region of said zone.

4. The process of claims 1, 2 or 3 wherein the rate of flow of the downwardly flowing water is correlated to the rate of flow of pulp, and the rate of underflow to maintain a substantially constant upper level in said zone.

5. The process of claims 1, 2 or 3 wherein the upwardly moving stream of air bubbles is produced by passing air, at a pressure of up to about 20 psig through a perforated member.

6. The process of claims 1, 2 or 3 wherein the upwardly moving stream of air bubbles is produced by passing air, at a pressure of up

to about 20 psig through a perforated member and wherein the perforated member has perforations of a size of about 5 microns to about 2500 microns.

7. The process of claims 1, 2 or 3 wherein the upwardly moving stream of air bubbles is produced by passing air, at a pressure of up to about 20 psig through a perforated member and wherein the air bubbles have a size of about 1000 microns to about 10,000 microns.

8. The process of claims 1, 2 or 3 wherein the aqueous slurry has a solids content of about 10-50%.

9. The process of claims 1, 2 or 3 wherein said slurry includes a surface active agent to control the size of the air bubbles.

10. The process of claims 1, 2 or 3 wherein the upwardly moving stream of air bubbles is produced by passing air through a perforated member, the pressure of air being defined by the formula

$$p = hd - k$$

wherein  $p$  is the pressure

$h$  is the height of the zone

$d$  is the average density of the contents within said zone

and  $k$  is a factor which is greater than 0 but less than 7.

11. Apparatus comprising:

- (a) a vertically elongated column provided with jacketing means for maintaining a temperature higher than ambient within said column;
- (b) means for introducing water at a temperature hotter than ambient at the upper portion of said column;
- (c) means for introducing a hot aqueous pulp to an intermediate portion of said column;
- (d) means for introducing air bubbles into the lower portion of said column;
- (e) means for collecting a liquid constituent of said pulp from the upper portion of said column in the form of a foam;
- and (f) means for discharging a solid constituent of said slurry from the lower portion of said column.

## 12. Apparatus comprising:

- (a) a vertically elongated column including an upper zone, an intermediate zone and a lower zone, said zones each being provided with jacketing means for maintaining a temperature higher than ambient within said column;
- (b) water inlet means extending into the upper portion of said upper zone;
- (c) inlet means for introducing a hot aqueous pulp to said intermediate zone;
- (d) means for introducing air bubbles into said lower zone;
- (e) means for collecting a liquid and a selected solid constituent of said pulp from the upper portion of said lower zone;

and (f) means for discharging another solid constituent of said pulp from the lower portion of said lower zone.

13. The apparatus of Claims 11 or 12 wherein the cross-sectional area of said upper zone is about  $1/4$  to  $3/4$  of the cross-sectional area of said intermediate and said lower zones.

14. The apparatus of Claims 11 or 12 wherein the cross-sectional area of said upper zone is about  $1/4$  to  $3/4$  of the cross-sectional area of said intermediate and said lower zones and wherein said upper zone is of reduced diameter than the diameter of said intermediate and lower zones.

15. The apparatus of Claims 11 or 12 wherein the cross-sectional area of said upper zone is about  $1/4$  to  $3/4$  of the cross-sectional area of said intermediate and said lower zones and wherein said upper zone is provided with a solid member spaced from the interior walls thereof to provide such reduction in cross-sectional area.

16. The apparatus of Claims 11 or 12 wherein the cross-sectional area of said upper zone is about  $1/4$  to  $3/4$  of the cross-sectional area of said intermediate and said lower zones and wherein said upper zone is provided with an axial hollow slurry inlet means extending to said

intermediate zone with an aperture therein communicating with said intermediate zone, to provide such reduction in cross-sectional area.

17. The apparatus of Claims 11 or 12 wherein the cross-sectional area of said upper zone is about  $1/4$  to  $3/4$  of the cross-sectional area of said intermediate and said lower zones and wherein said upper zone is provided with an axial hollow slurry inlet means extending to said intermediate zone with an aperture therein communicating with said intermediate zone, to provide such reduction in cross-sectional area and wherein said water inlet means is concentric with said axial hollow slurry inlet means.

18. The apparatus as claimed in Claims 11 or 12 wherein said air bubble introducing means comprises a conical member, whose walls are fluted and perforated, said member communicated with a source of air under pressure.

19. The apparatus as claimed in Claims 11 or 12 wherein said air bubble introducing means comprises a conical member, whose walls are fluted and perforated, said member communicated with a source of air under pressure and wherein said perforations are of a size of about 5 microns to about 2500 microns.

20. The apparatus as claimed in Claims 11 or 12 wherein said air bubble introducing means comprises an ellipsoidal cylinder, the upper ellipsical cross-sectional portion being perforated, said cylinder communicating with a source of air under pressure and wherein said perforations are of a size of about 5 microns to about 2500 microns.



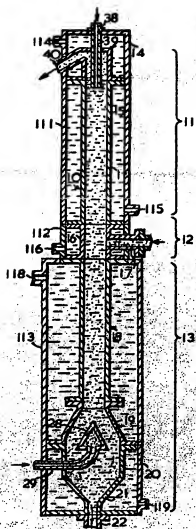


FIG. 2

INVENTOR

P. BOUTIN

PATENT AGENTS

*Amesbury, Mass. 1911*  
*Amesbury, Mass. 1911*



FIG. 3

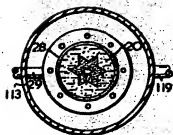


FIG. 4

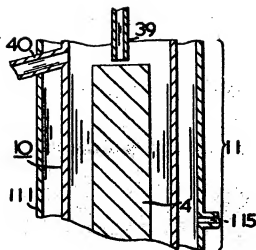


FIG. 5

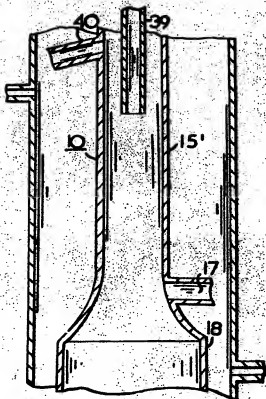


FIG. 6

INVENTOR

P. BOUTIN

PATENT AGENTS

*Charles H. Boutin & Co.*  
*Engineers & Patent Attorneys*

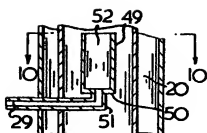


FIG. 9

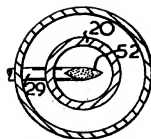


FIG. 10

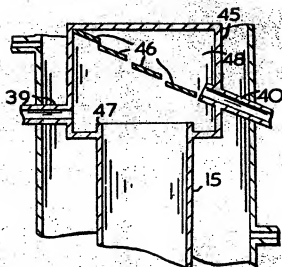


FIG. 8

INVENTOR

P. BOUTIN

PATENT AGENTS

*Attest*  
*Notary Public*